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RADIO-HOLLAND NV

Noordwijk, 6th Oct. 1970.

DIGIPLOT - ITS POTENTIAL FOR SAFETY OF NAVIGATION

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To be able to set out clearly the contribution which Digiplot will make in ships using radar for navigation in poor visibility and in crowded waters, it is necessary to describe briefly what has to be done in its absence.

Considering firstly the collision aspect of the matter, most mariners agree that the degree of risk of collision with any target which, within a reasonable range, is closing or might do so if own ship had to alter course, should always be examined. Also that the assessment for any of them which appear to be coming within 3 or 4 miles requires more accuracy than can be obtained by eye and echo trails. In other words, some form of computation is needed.

The relevant questions here to be examined are the load of work and responsibility on the observer or the master and the care and accuracy required. A point of the highest significance, which is sometimes overlooked, is that no assessment, however exact, is valid beyond the moment of the last observation, so that the confirmation and up-dating of every appraisal on which reliance is to be placed must be continuous. This is of particularly urgent importance when one ship has commenced manoeuvring action to disengage and untoward action by other vessels has to be guarded against; with some methods of plotting this is the Achilles heel, because, when own ship's course and/or speed are changing, the firm basis for the geometry has been removed and will not be recovered until the ship is steady again.

Without becoming involved in a true or relative plotting controversy, it may be said that the degree of risk of collision is usually thought of in the terms "How close -- How soon"; more professionally expressed as the distance and time of CPA (closest position of approach). It is also generally agreed that, for the most effective determination of avoiding action, it is necessary to know the true courses and speeds of threatening vessels, which will give something approaching a visual appreciation of the situation.

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DIGIPLOT™
A FULLY AUTOMATIC MARINE RADAR DATA PLOTTER

by Captain F.J. Wylie, R.N. (RET.) and
John C. Herther, president
Iotron Corporation

ABSTRACT

This paper will discuss the increasing work in crowded waters, involved in the proper use of radar with manual plotting systems and the take over of all the labour from the observer, by Iotron's fully automatic marine radar data plotter type DIGIPLOT, with digital data read out.
Iotron will show that the DIGIPLOT can do the job with the same efficiency for 80 targets as for one, when the ship enters areas of heavy traffic and that the system at the same time may avoid human mistakes and inaccuracies.

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The amount of work required to attain these objectives depends very much on the degree of sophistication present in the equipment, which may vary from a manoeuvring diagram, or even a plain sheet of paper, to a fully automated all-echo tracker. The mental effort and strain involved also varies with the amount of accurate data measurement needed and the continuous appraisal to ensure that the correct targets are under examination and valid deductions are being drawn; one aspect of the latter is the assurance needed that any automation employed is giving coherent answers.

The work could be broken down into a large number of steps, but, for the purpose of this examination, it should be sufficient to divide it into eight items:-

(i) Echo selection.

(ii) Data measurement.

(iii) Plotting tracks and vector diagrams.

(iv) Placing the threats in an order of priority.

(v) Planning manoeuvring action needed to avoid the top priority target-s without increasing dangerously the threats from others.

(vi) Watching the movements of other ships during manoeuvring action by own ship.

(vii) Planning the return to the original course or further action.

(viii) Checking frequently that new echoes appearing are given their appropriate places in the plan.

The implications of most of these items will be obvious and the need to enlarge on some of them is only to show the different degrees in which they apply to the various systems. Taking them in the order in which they occur:-

(i) Echo selection. Of course, selection of the most threatening echoes about which precise information is needed will only occur when there are more echoes of interest on the screen than can be dealt with simultaneously. In manual plotting systems this means more than one observer team can cope with; in an automatic system there may be a fixed limit to the number of echoes it will track.

(ii) Data measurement. This entails reading off the ranges and bearings of echoes at frequent intervals. The maximum accuracy that the system will allow is required. The measurement is only required in the simplest systems where the observer has to transfer the readings manually to the plot.

(iii) Plotting tracks and vector diagrams. This is perhaps the most laborious part of the work and it is required in all the manual systems and the semi-automatic types.

A complication must be added here. In the very simplest systems, such as plotting on a chart or a sheet of paper, there is free choice whether the plot should be true or relative; with a manoeuvring board, RAS Plotter and some semi-automatic systems the plot is intended to be relative; with the reflection plotter and some semi-automatic systems the plot has to be in the same mode as the radar display. With the fully automatic systems the choice is free.

(iv) Placing the threats in an order of priority. This is largely a matter of comparing the CPA distances and times of the threatening echoes; obviously a responsible task but, if there are only one or two echoes, not a very onerous one. However, if there several echoes which might produce awkward situations, it is not an easy task with the manual systems. Great assistance is given to the observer by those fully automatic systems which show echo velocity vectors based on a pre-selected time interval ahead. It has to be remembered that some of the automatic systems cater only for a limited number of echoes and those not selected may change their degree of threat unnoticed.

(v) Planning manoeuvring action. With the manual systems the effect on the relative track and hence the CPA of each echo of an alteration of course and/or speed by own ship can be predicted by simple geometry. In a multiple-ship situation this will be a laborious task. All the fully automatic systems provide a prediction of the new relative tracks of echoes consequent on a given change of own ship's movement. Some of them, as already stated, deal with only a limited number of echoes.

(vi) Watching the movements of other ships during manoeuvring action by own ship. This is necessary to ensure that inimical action by others is not upsetting the plan. As stated in an earlier paragraph, it is almost impossible to achieve with manual systems but the fully automatic systems will keep the target ship vectors up to date.

(vii) Planning the return to the original course. A somewhat laborious task with the manual systems but straightforward when up-dated relative vectors are provided automatically.

(viii) Checking for new echoes. This is necessary in all systems which do not either plot or vector all echoes. All the above clauses are concerned if they are applicable to the system in use.

Having covered very briefly the work involved in the use of radar for collision avoidance, it remains to discover how much of the load may be taken off the operator by DIGIPLOT. Taking the same eight points:-

(i) Digiplot deals with all echoes passed to it by the radar. It examines all ship echoes against criteria set by the operator in terms of a CPA distance (presumably the closest to be tolerated) and a time interval. It places the echoes in an order of "threat priority" and displays the 40 which are highest on the list.

(ii) No data measurement required.

(iii) No plotting. Vectoring is automatic for all echoes displayed (see (i)). Vectors may be true or relative at will, instantly switched. The display is permanently centred.

(iv) Any of the echoes displayed which will fall within the criteria set (see (i)) are shown brighter than the others.

(v) Proposed action may be tested by the automatic prediction system. This goes through the whole progress of the alteration showing the changed vectors of all echoes (up to 40) but it is speeded up 30 times and so is completed in a few seconds.

(vi) The true or relative vectors of the target ships will, of course, be seen all through the actual manoeuvre. If true vectors are shown, any change of course by a target ship will become apparent very rapidly. Extremely close supervision of any one echo may be kept by selecting it for display on the digital read-out. Its course and speed, CPA distance and time etc., are shown, up-dated every scan.

(vii) The automatic display of relative vectors will show clearly when the danger from threatening echoes is past and course may be resumed.

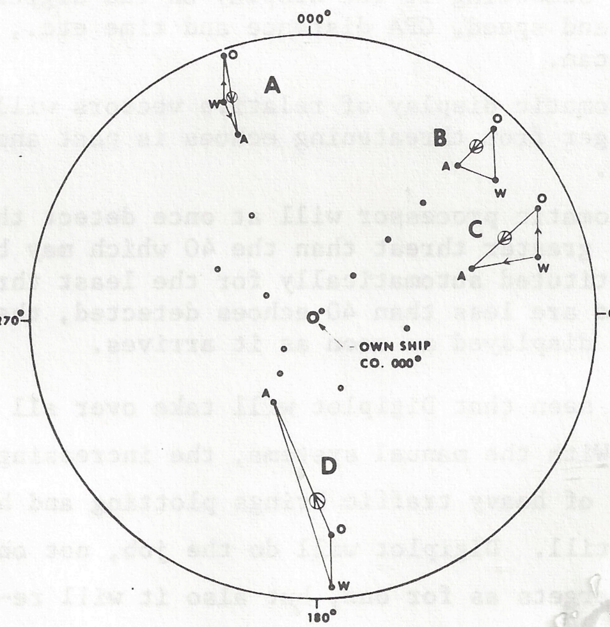
(viii) The automatic processor will at once detect the arrival of an echo of greater threat than the 40 which may be displayed; it will be substituted automatically for the least threatening of the 40. If there are less than 40 echoes detected, the new one, of course, will be displayed as soon as it arrives.

Thus, it will be seen that Digiplot will take over all the labour of plotting from the observer. With the manual systems, the increasing number of targets as ships enter areas of heavy traffic brings plotting and hence the proper use of radar to a standstill. Digiplot will do the job, not only with the same efficiency for 80 targets as for one, but also it will re-survey the whole situation every scan, say 3 seconds. As there is no data measurement, transfer or manual geometry, several areas of human blunders and inaccuracies are avoided. The difficulty of weighing one threat against another is greatly lightened and the continual re-appraisal needed particularly in crowded circumstances, is removed from the impossible to the commonplace.

The observer will still have to appraise the situation but he will be able to see it as a whole and free from anxiety as to the correctness of his choice of targets or of changes in target behaviour occuring while he is absorbed in calculation.

It will be wise to site Digiplot alongside the radar PPI. This will provide ready assurance that the automatic system is giving valid intelligence and will afford the convenience of having each on the range scale appropriate to the use being made of it. As well as the range scale setting, the choice of true or relative vectors and north upward or head upward orientation may be made on Digiplot quite independent of the settings in use on the parent radar.

For navigating in the vicinity of land, the echo of a known fixed point may be used as the target for the digital read-out and the ranges and bearings then shown may be used for plotting on the navigational chart. The course and speed readings on such targets may be used as inputs for the set and drift controls.



O AND A IN EACH CASE ARE PLOTTED RADAR DATA.
OA IS THE RELATIVE TRACK.
WO IN EACH CASE IS OWN SHIP'S TRUE COURSE AND DISTANCE RUN IN X MINUTES.
WA IN EACH CASE IS OTHER SHIP'S TRUE COURSE AND DISTANCE RUN IN X MINUTES
THE PLOTTING TIME INTERVAL IS THE SAME IN EACH CASE.

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RADIO-HOLLAND NV

Noordwijk, 6th Oct. 1970.

DIGIPLOT - OPERATING FEATURES AND DESIGN

by John C. Herther, President
Iotron Corporation

The Iotron Corporation is dedicated solely to the design, development, production, sales and service of marine digital equipment.

DIGIPLOT, the Company's fully automatic marine radar data plotter, has been in design and development since early 1969. The production prototype was introduced to the marine community at Ships' Gear International in London in July 1970. Our first production unit has been brought to INFO for demonstration and will also be shown at Europort '70 in November.

Figure 1 is a photograph of the top of the equipment showing the pictorial display tube, the operator controls and the Digital Data Readout. In the photograph, the controls are set to provide a north-up, true plot on a 12 mile range scale. Own ship is shown as the brighter than normal vector in the center. The vectors correspond to a future position prediction time of 12 minutes. Own ship's course is 230° speed is 15 knots with set and drift properly compensated as evidenced by the lack of vector on a known stationary target bearing 224° range 10½ miles. The threatening vessel off the starboard bow is almost within the alarm threshhold.

By placing the target selector on the vector, the target is identified and digital data may be requested by push button. The Digital Data Readout indicates a 0 mile CPA in 8.4 minutes for the target bearing 248° at 3½ miles. (Course 090°, speed 12 knots.)

DESIGN

Figure 2, the functional block diagram, shows required inputs and internal operations. It is noted that only those signals normally furnished to a slave display are required from the basic radar. No radar modification is required. Signals supplied from the gyro compass are digitally converted for use in subsequent computation. Ship's speed is required in the plotting computations; therefore, if a ship's log is available, it is connected directly to DIGIPLOT and its output is digitized.

Antenna azimuth signals from the junction box, which are normally used to drive a slave radar PPI display, are digitized to provide target relative bearing. The radar video signal from the junction box is fed into the video processor, which identifies echoes in the presence of clutter, and separates small from "extended" targets. Targets whose "equivalent echoing area" is greater than the largest vessel's echoes are classified as extended, and the range and bearings of the closest edge are processed for display on the cathode ray tube (CRT). Since own ship is always displayed at the center of the CRT, the land mass will appear to move equal and opposite to own ship's motion. This data is updated every antenna scan.

In contrast, the range and bearing coordinates for all small targets are evaluated in the central processor as candidates to be tracked. A conventional track-while-scan method is used, similar to air traffic control systems. The video processor analyzes all echoes within a range of 17 miles and establishes a track for any target which appears at nearly the same co-ordinates on two successive scans. Multiple returns from the same target are also sensed and classified correctly. Tracks on the 80 closest targets are maintained, with CPA distance and time-to-CPA being used for ranking and choosing the 40 most threatening for display. Thus, if 40 targets are displayed, and a target not shown becomes more dangerous, it replaces the least threatening target on the CRT. The inherent design limitations of 80 target tracks and 40 displayed are considered more than sufficient for any operational system.

The plan position of each target is shown on the CRT by inscribing a small circle at the position of the echo, similar to the display of the adjacent radar PPI. The DIGIPLOT display may be instantly switched from North-up to stabilized Head-up, and between 12, 6, 3 and 1½ mile range scales. This instantaneous switching is accomplished independent of the settings on the "parent" radar.

Subsequent range and bearing data obtained on each scan of the radar antenna completely updates all computations for all targets being tracked. After 10 scans reasonably stable course and speed vectors are displayed and after 20 scans, full accuracy is achieved for the more dangerous high speed targets. Low speed targets take a somewhat longer time to stabilize and achieve full accuracy. The display may be viewed either as a true or relative plot and may be switched instantly from one to the other. Target motion is presented along true or relative courses, and length of vector displayed is proportional to their true or relative speed. The vector length is continuously adjustable in terms of time, in minutes, selected for predicting future positions. It should be appreciated that the course and speed for each target is displayed in real time, i.e., as a target changes course and/or speed, the vector associated changes accordingly with a slight time delay.

Adjustment of set and drift controls is not required for normal anti-collision maneuvering. They may be adjusted as in true motion radar in that once a fixed target is identified, its vector may be removed by adjusting the controls.

Alarm conditions for CPA distance and time-to-CPA are selected by the operator. Targets whose predicted CPA values are less than the settings trigger an audio and visible alarm. Alarming vectors are shown brighter than normal. The audio alarm may be silenced at the operator's discretion, but will be re-sounded when a subsequent alarming situation occurs.

Digital Data Readout provides a numerical display of range and bearing, course and speed, and CPA distance and Time-toCPA for any target. The data thus displayed is continuously updated every radar scan. The desired target is selected by placing a light-sensitive pointer directly over the targets displayed position on the scope. Own ship's course and speed may also be selected for display. Monitoring of course and speed of a threatening target gives prompt warning of its maneuvers.

By selecting a known fixed-point as a target, the values displayed for course and speed establish inputs for the "set" and "drift" controls. The courses and speeds of all targets displayed are thereby accurately corrected to values being made good over the ground.

In pilotage waters, range and bearing values of known fixed points can be continuously displayed. This provides extremely accurate radar data for direct plotting on a navigation chart.

Own ship's dynamic characteristics are entered at the time of installation. These include acceleration, deceleration, and turning rates as a function of speed including advance and transfer for standard rudder and load conditions. These characteristics are used for predicting the effect of trial maneuvers, assuming all other targets maintain course and speed. The progress of the predicted maneuver is displayed in its entirety, but speeded up 30 times. It may be shown as either a true or relative plot displaying the appropriate vectors for all targets (and own ship in true motion). Release of the trial control button (which must be depressed for the prediction) restores the display of the current actual situation. During the trial maneuver, DIGIPLOT continues to monitor the actual situation and alarming targets will still be detected and the alarm triggered.

EQUIPMENT

Digital circuits are utilized because of their inherent higher reliability. They incorporate integrated circuits (IC's) which operate at very low voltage, are insensitive to environmental changes and voltage variations, and have been proven highly reliable in both manned and unmanned space vehicles. Large printed circuit boards (PCB's) involve minimum connections and are functionally divided to aid in fault finding. PCB's are easily removable, thus allowing easy maintainance using the repair-by-replacement technique. Figure 3 is a photograph showing internal access to the DIGIPLOT console.

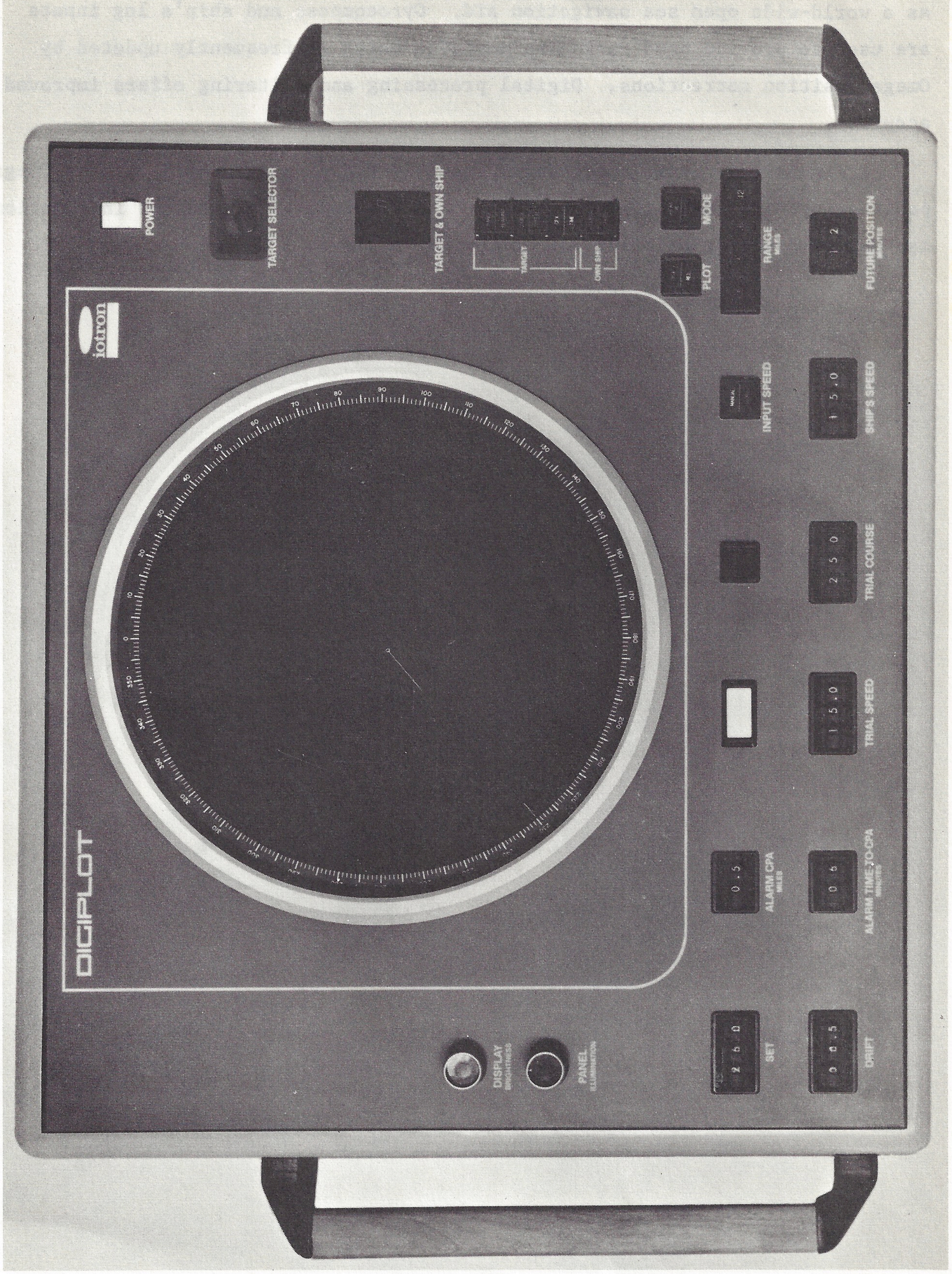
Within this service philosophy, the DC power supply is also removable and replaceable as a sub-assembly. Solid state deflection amplifiers and other analogue circuits mounted on small PCB's would be carried as ship's spares. The only electro-mechanical parts are the cooling blowers and panel controls. All materials in the system have been selected for the marine environment.

OPTIONS UNDER DEVELOPMENT

Any Omega receiver may be selected for use with a position computing option to automatically provide a continuous display of present latitude and longitude as a world-wide open sea navigation aid. Gyrocompass and ship's log inputs are used to provide dead reckoning position which is frequently updated by Omega position corrections. Digital processing and filtering offers improved accuracy.

A magnetic recorder continuously records the display as well as the Omega positioning data and a time reference. The previous 45 minutes of information can be preserved at any time for subsequent replay.

Figure 1


POWER
TARGET SELECTOR
TARGET & OWN SHIP
MODE
PLOT
RANGE
FUTURE POSITION
iotron
INPUT SPEED
SHIP'S SPEED
TRIAL COURSE
TRIAL SPEED
ALARM CPA
ALARM TIME-TO-CPA
DIGIPLOT
SET
DRIFT
DISPLAY
PANEL

DIGIPLOT FUNCTIONAL BLOCK DIAGRAM

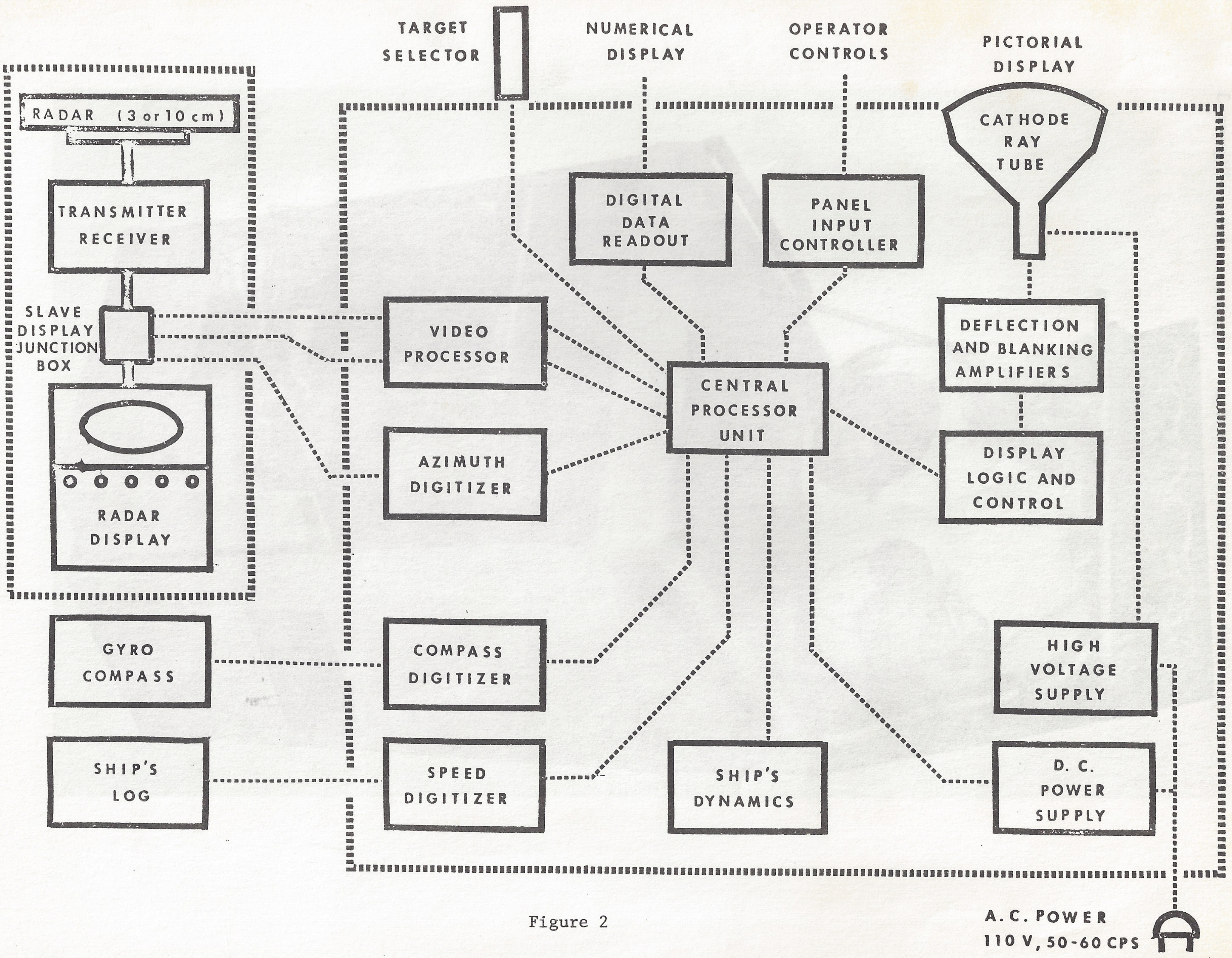


Figure 2

Figure 3